Chapter 2: Spine & Upper Extremity
I. Osteology
   A. Overview
      • Consists of stacks of vertebrae forming the vertebral column
      • Five sections:
         - Cervical: 7 vertebrae
         - Thoracic: 12 vertebrae
         - Lumbar: 5 vertebrae
         - Sacral: 5 fused vertebrae
         - Coccygeal: 5 fused vertebrae
      • Forms an S-shape as a result of two types of curvature
         - Primary curvature: develops intrauterine and is concave anterior
            ○ Shape of thoracic and sacral sections
         - Secondary curvature: develops after birth and is concave posterior
            ○ Shape of cervical and lumbar sections
            ○ Cervical section develops when baby lifts head up at six months old
            ○ Lumbar section develops when infant assumes upright position at one year old
      • Functions to maintain our upright posture by evenly displacing the weight of the body throughout
        the S-shaped vertebral column

B. Vertebrae
   • Vertebral body is the thick oval segment of a vertebra
     - Intervertebral discs separate the vertebrae and provide cushion for weight-bearing and movement
       of the vertebral column
     - One of the sites of adult hematopoiesis
Pedicles project posterolaterally from the vertebral body
- Laminae begin at the pedicles and join posteriorly to form the base of the spinous process, which projects posteriorly
- Transverse processes project laterally from the junction of the pedicles and lamina
- Vertebral foramen is a space that is formed by the posterior aspect of the vertebral body, pedicles and lamina
  - Contents: spinal cord, meninges, vertebral vessels, adipose tissue and spinal roots
- Vertebral canal is formed by the stacking of the vertebral foramen
- Vertebral arch is formed by the pedicles and lamina
- Superior and inferior articular processes are bony prominences that extend out from the junction of the pedicle and lamina

C. Intervertebral Facet Joints
- Formed by the articulation of a superior articular facet of the inferior vertebra with the inferior articular facet of the superior vertebra

D. Pars Interarticularis
- Bony part of the vertebra at the junction of the pedicle and lamina that lies between the superior and inferior articular processes of the facet joint
- On a radiograph of the lumbar spine the pars is referred to as the neck of a Scottie dog image formed by an outline of surrounding vertebral structures

E. Cervical Spine
- C1 vertebra (Atlas)
  - Articulates with the occipital condyles of the occipital bone to form the junction between the spine and the skull called the atlanto-occipital joint
    - Allows the head to nod up and down
  - Has no vertebral body
  - Ring like structure formed by anterior and posterior arches and two lateral masses
    - Anterior arch
      - Anterior surface is convex shaped and at its center is the anterior tubercle, which serves as the attachment of the longus coli muscles and the anterior longitudinal ligament
      - Posterior surface is concave shaped and contains at its center an oval facet for articulation with the dens (odontoid process) of the axis (C2 vertebra)
    - Posterior arch contains the posterior tubercle, which gives origin to the nuchal ligament
  - Lateral masses
    - Superior facets receive the occipital condyles
    - Inferior facets articulate with the axis and allow rotational movements of the head
  - Large transverse processes that project laterally from the lateral masses
    - Transverse foramen contains the vertebral arteries before they enter the skull
Jefferson Fracture
- Fracture of the anterior and posterior arches in one or more places
- Mechanisms of injury: axial loading of the head onto the spine or direct impact to the posterior aspect of the cervical spine
- Presentation: neck pain, often with no neurological symptoms
- Fracture can result in damage to the arteries in the neck potentially causing Horner’s syndrome, ataxia and inability to sense pain or temperature
- Diagnosis: X-ray and CT
- Treatment: if stable put patient in collar immobilization, if unstable surgical fixation
  i. Stability is partially determined by the integrity of the transverse ligament connecting the lateral masses of the atlas
  ii. If on an axial CT, the atlantodental interval (ADI) is measured to be larger than 3mm, then the transverse ligament is considered torn and the fracture is unstable

C2 vertebra (Axis)
- Forms the rotational base for the atlas and skull
- Unlike C1, C2 has a vertebral body with a prominent projection called the dens
  - Oval circular facet on its anterior surface for articulating with the anterior arch of C1
  - Allows C1-C2 rotation
  - Primary horizontal stabilizer of the atlanto-axial joint
- Hangman’s Fracture
  - Fracture of both the pedicles or pars interarticularis of the C2 vertebra
  - Causes: falls, especially in the elderly; motor vehicle accidents due to hyperextension of the neck; axial loading onto the C2 vertebra
  - Mechanism of injury: sudden forceful hyperextension of the head just under the chin that occurs mainly with deceleration injuries
  - Treatment: neck collar or surgery
C3-C7 vertebrae
  - Vertebral bodies with uncinate processes
    - Thin bony prominences that hook out from each side of the body’s superior surface
    - Along with the intervertebral discs prevents translation of the vertebra off of the vertebra below it and limits lateral flexion
    - T1 vertebra also has uncinate processes
  - Spinous processes are short and bifid
  - Superior and inferior articular facets are flat and oval shaped bony prominences located at the junction of the pedicle and lamina
  - Transverse processes contain transverse foramen, which contains the vertebral artery and vein and a plexus of sympathetic nerves
  - Vertebral prominens is the distinctive and long spinous process of the C7 vertebra
    - First palpable spinous process
  - C3-C7 vertebrae
  - Vertebral bodies with uncinate processes
    - Thin bony prominences that hook out from each side of the body’s superior surface
    - Along with the intervertebral discs prevents translation of the vertebra off of the vertebra below it and limits lateral flexion
    - T1 vertebra also has uncinate processes
  - Spinous processes are short and bifid
  - Superior and inferior articular facets are flat and oval shaped bony prominences located at the junction of the pedicle and lamina
  - Transverse processes contain transverse foramen, which contains the vertebral artery and vein and a plexus of sympathetic nerves
  - Vertebral prominens is the distinctive and long spinous process of the C7 vertebra
    - First palpable spinous process

F. Thoracic Spine
  - Heart shaped vertebral bodies that possess on both sides two costal facets: one near the base of the pedicle and the other anterior to the inferior vertebral notch
  - Transverse processes’ terminal concave surface articulates with the tubercle of the rib

G. Lumbar Spine
  - Kidney shaped vertebral bodies
  - Vertebral complex: transition point between the T12 and L1 vertebrae that consists of a change in curvature from the thoracic vertebrae to the lumbar vertebrae
    - Dramatic change in curvature creates instability at this point
    - Most common site of vertebral column body fractures
H. Ligaments
- Anterior Longitudinal Ligament (ALL): thick sheet like ligament that runs down the anterior surfaces of all the vertebral bodies
  - Prevents anterior displacement of intervertebral discs and hyperextension of the spine
- Posterior Longitudinal Ligament (PLL): runs within the spinal canal and extends from the C2 vertebra along the posterior surfaces of the vertebral bodies
  - Prevents posterior displacement of intervertebral discs and hyperflexion of the spine
- Ligamentum flavum: attaches adjacent vertebral lamina
  - High elastic tissue content that provides elastic recoil to vertebral column after flexion
  - Protects spinal cord posteriorly
- Supraspinous ligament: spans between the tips of adjacent spinous processes beginning at the C7-T1 vertebral level
- Interspinous ligament: attaches adjacent spinous processes
- Interttransverse ligament: attaches between adjacent transverse processes
- ALL is much stronger than PLL

II. Intervertebral Discs
A. Disc Structure
- Fibrocartilaginous ovoid shaped structures that lie between adjacent vertebral bodies forming a symphysis joint
- Functions to allow movement between adjacent vertebral bodies and act as shock absorbers
- Two components
  - Nucleus Pulposus: gel-like core that consists of proteoglycans, glycosaminoglycans and collagenous fibers immersed in mucoid material
  - Annulus Fibrosus: fibrocartilage ring made up of collagen types I and II
B. Disc Herniations
- Results from breakdown of the annulus fibrosus allowing a portion of the nucleus pulposus to herniate out, which can potentially compress the spinal nerves and/or roots
- Intervertebral discs usually herniate adjacent to the lateral edge of the PLL
Most commonly occurs in the cervical and lumbar regions of the spine
  - Rare in the thoracic region because those vertebrae undergo less movement due to being fixated by the ribs

### III. Back Muscles

#### A. Deep Muscles
- Extend from the pelvic bones along the length of the spine to the base of the skull
- Involved in movements of the spine
- All are innervated by the dorsal rami of the spinal nerves
- Divided into three layers: deep, intermediate and superficial
- Deep layer
  - Group of three muscles that attach between the transverse and spinous processes of the vertebral column

#### Table 2.1: Deep Layer of the Deep Muscles

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Origin</th>
<th>Insertion</th>
<th>Movement</th>
<th>Innervation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semispinalis</td>
<td>▪ Transverse processes of C4-T10</td>
<td>▪ Spino processes of C2-T4</td>
<td>▪ Extension of the head and spine</td>
<td>▪ Dorsal primary rami of spinal nerves</td>
</tr>
</tbody>
</table>
| Multifidus | ▪ Sacrum  
▪ Posterior iliac spine  
▪ Transverse processes of T1-T3  
▪ Articular processes of C4-C7 | ▪ Spino processes of vertebrae   | ▪ Stabilization of the spine                      | ▪ Dorsal primary rami of spinal nerves           |
| Rotatores | ▪ Vertebral transverse processes                                  | ▪ Lamina and spino processes of the immediately superior vertebra | ▪ Stabilization of the spine                      | ▪ Dorsal primary ramus of spinal nerves          |

- Intermediate Layer
  - Group of three muscles collectively called the erector spinae muscles
  - All three arise from a common tendinous origin that attaches to: sacroiliac and supraspinous ligaments, iliac crest, sacrum, lumbar and thoracic vertebrae
Table 2.2: Intermediate Layer of Deep Muscles

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Origin</th>
<th>Insertion</th>
<th>Movement</th>
<th>Innervation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iliocostalis</td>
<td>Sacrum, iliac crest, spinous processes of lumbar/thoracic vertebrae</td>
<td>Ribs</td>
<td>Unilaterally: flex the spine, bilaterally: extend the spine and head</td>
<td>Dorsal primary rami of spinal nerves</td>
</tr>
<tr>
<td>Longissimus</td>
<td>Sacrum, iliac crest, spinous processes of lumbar/thoracic vertebrae</td>
<td>Ribs, transverse processes of C2-T12, mastoid process</td>
<td>Unilaterally: flex the spine, bilaterally: extend the spine and head</td>
<td>Dorsal primary rami of spinal nerves</td>
</tr>
<tr>
<td>Spinalis</td>
<td>Sacrum, iliac crest, spinous processes of lumbar/thoracic vertebrae</td>
<td>Spinous processes of C2 and T1-T8, occipital bone</td>
<td>Unilaterally: flex the spine, bilaterally: extend the spine and head</td>
<td>Dorsal primary rami of spinal nerves</td>
</tr>
</tbody>
</table>

- **Superficial Layer**
  - Two muscles on the posterior aspect of the cervical spine that move the head and neck

Table 2.3: Superficial Layer of Deep Muscles

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Origin</th>
<th>Insertion</th>
<th>Movement</th>
<th>Innervation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Splenius Capitis</td>
<td>Inferior aspect of ligamentum nuchae, spinous processes of C7-T3</td>
<td>Mastoid process, occipital bone</td>
<td>Rotate the head to the ipsilateral side</td>
<td>Dorsal primary rami of spinal nerves C3 and C4</td>
</tr>
<tr>
<td>Splenius Cervicis</td>
<td>Spinous processes of T3-T6</td>
<td>Transverse processes of C1-C4</td>
<td>Rotates the head to the ipsilateral side</td>
<td>Dorsal primary rami of lower cervical spinal nerves</td>
</tr>
</tbody>
</table>

Figure 2.19: Superficial Layer of Deep Back Muscles
Figure 2.20: Intermediate and Superficial Back Muscles
B. Intermediate Muscles
   - Two muscles involved in moving the thoracic cage to assist in respiration
   - Innervated by the intercostal nerves

Table 2.4: Intermediate Muscles

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Origin</th>
<th>Insertion</th>
<th>Movement</th>
<th>Innervation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serratus Posterior</td>
<td>Inferior ligamentum nuchae, Cervical and</td>
<td>Ribs 2-5</td>
<td>Elevates ribs 2-5</td>
<td>Intercostal</td>
</tr>
<tr>
<td>Superior</td>
<td>thoracic vertebrae</td>
<td></td>
<td></td>
<td>nerves</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Serratus Posterior</td>
<td>Thoracic and lumbar vertebrae</td>
<td>Ribs 9-12</td>
<td>Depresses ribs 9-12</td>
<td>Intercostal</td>
</tr>
<tr>
<td>Inferior</td>
<td></td>
<td></td>
<td></td>
<td>nerves</td>
</tr>
</tbody>
</table>

C. Superficial Muscles
   - Deep to the skin and contribute to movement of the shoulder and upper extremity
   - Arise from the vertebral column and insert onto bones of the shoulder

Table 2.5: Superficial Muscles

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Origin</th>
<th>Insertion</th>
<th>Movement</th>
<th>Innervation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trapezius</td>
<td>Skull, Ligamentum nuchae, Spinous processes</td>
<td>Clavicle, Acromion, Scapular spine</td>
<td>Elevates, retracts, depresses and rotates</td>
<td>Spinal Accessory</td>
</tr>
<tr>
<td></td>
<td>of C7-12</td>
<td></td>
<td>scapula</td>
<td>nerve (CN XI)</td>
</tr>
<tr>
<td>Latissimus Dorsi</td>
<td>Spinous processes of T6-T12, Iliac crest</td>
<td>Intertubercular groove of the humerus</td>
<td>Extends, adducts and medially rotates the</td>
<td>Thoracodorsal</td>
</tr>
<tr>
<td></td>
<td>Thoracolumbar fascia, Lower ribs</td>
<td></td>
<td>upper extremity</td>
<td>nerve</td>
</tr>
<tr>
<td>Levator Scapulae</td>
<td>Transverse processes of C1-C4</td>
<td>Medial border of the scapula</td>
<td>Elevates the scapula</td>
<td>Dorsal scapular</td>
</tr>
<tr>
<td>Rhomboids (Major and</td>
<td>Major: spinous processes of T2-T5, Minor:</td>
<td>Medial border of scapula (minor is superior</td>
<td>Retract and rotate the scapula</td>
<td>Dorsal scapular</td>
</tr>
<tr>
<td>Minor)</td>
<td>spinous processes of C7-T1</td>
<td>to major)</td>
<td></td>
<td>nerve</td>
</tr>
</tbody>
</table>

D. Thoracolumbar Fascia
   - Thick deep investing fascia of the muscles of the back
   - Anterior layer lies anterior to the erector spinae muscles and attaches to the transverse processes of the vertebrae
   - Posterior layer lies posterior to the erector spinae muscles and attaches to the spinous processes of the vertebrae
   - Following muscles attach to it: latissimus dorsi and abdominal wall muscles (internal oblique and transverse abdominis)
IV. Neural Structures

A. Spinal Cord

- Occupies ⅔ of the vertebral canal and is enveloped by the meninges along its entire length
- Grey matter is in the central region of the cord and contains neuron cell bodies
  - Motor neuron cell bodies are located in the ventral horn
  - Autonomic neuron cell bodies are located in the lateral horn
  - Sensory neuron cell bodies are located in the dorsal horn and in the dorsal root ganglion
- White matter is located peripherally and contains neural tracts traveling to and from the brain
- Conus medullaris: terminal end of the spinal cord located at the T12/L1 vertebral level
- Dural sac: continuation of the dura beyond the conus medullaris that houses the cauda equina and is the terminal fixation point via the filum terminale
- Cauda equina: collection of the final lumbar and sacral spinal nerves (L2-S5) that continue on from the conus medullaris within the dural sac and are bathed in CSF
  - Provide visceral innervation to the pelvic organs (e.g. bladder) and motor and sensory innervation to the perineum and lower extremity
- Filum terminale is a long fibrous tissue cord that spans from the apex of the conus medullaris to coccygeal vertebrae and is composed of two parts:
  - Filum terminale internum: extension from the pia mater that travels within the dural sac and inserts into the tip of the dural sac around the second sacral vertebra
  - Filum terminale externum: extends from the apex of the dural sac and inserts into the first segment of the coccyx (AKA coccygeal ligament)
- Lumbar puncture is a diagnostic procedure used to collect sample CSF
  - Insert the needle below the L2 vertebral level to avoid spinal cord injury
  - Needle is advanced into the dural sac between the L3-L5 vertebral levels to collect CSF around the cauda equina
    - Iliac crest can be used as a landmark because it is at the same level as the intervertebral disc between L4/L5
  - Layers pierced: skin, superficial fascia, supraspinous ligament, interspinous ligament, ligamentum flavum, epidural space, dura mater and arachnoid mater
    - Epidural anesthesia block stops at the epidural space and is inserted in the same region to avoid injury to the spinal cord
B. Spinal Nerves

- Exit through the intervertebral (neural) foramen, which are formed by the following structures:
  - Anterior: posterolateral aspect of superior vertebra and intervertebral disc
  - Posterior: facet joints
  - Superior: inferior vertebral notch of the superior pedicle
  - Inferior: superior vertebral notch of the inferior pedicle

![Figure 2.24: Lateral View of Cervical Vertebra](image1)

![Figure 2.25: Cervical Spinal Nerves](image2)

- Cervical spinal nerves
  - Travel above the corresponding vertebra’s pedicle, then exit through the intervertebral foramen
    - Example: C5 spinal nerve travels above the C5 vertebra’s pedicle, then exits through the intervertebral foramen between the C4 and C5 vertebrae
  - Cervical disc herniations compress the spinal nerve corresponding to the lower vertebra
    - Example: disc herniation at C5/C6 vertebral level will compress the C6 spinal nerve
    - Most common cervical levels for disc herniation: C4/C5, C5/C6 and C6/C7
    - Symptoms manifest in the upper extremity
    - Can involve sensory and motor deficits and/or changes in reflexes
    - Cervical radiculopathy: impingement of cervical roots and/or spinal nerves, which results in pain/numbness radiating down the upper extremity
  - Special cervical spinal nerves
    - C1 spinal nerve only carries motor fibers
    - C2 spinal nerve directly gives rise to the greater occipital nerve, which pierces the trapezius muscle and provides cutaneous innervation to the posterior part of the scalp
    - C8 spinal nerve exits below the pedicle of C7 vertebra and all subsequent spinal nerves exit below the corresponding vertebra’s pedicle
  - Cervical spinal nerve reflexes
    - C5 – biceps brachii
    - C6 – brachioradialis
    - C7 – triceps brachii
Spine & Upper Extremity

Figure 2.26: Lateral View of Lumbar Vertebrae

- Lumbar spinal nerves
  - Travels below the corresponding vertebra’s pedicle, then exits through the intervertebral foramen
    - Example: L4 spinal nerve travels below the L4 vertebra’s pedicle, then exits through the intervertebral foramen between the L4 and L5 vertebrae
  - Lumbar disc herniations compress the spinal nerve corresponding to the lower vertebrae
    - Example: disc herniation at L4/L5 vertebral level will compress the L5 spinal nerve
    - Symptoms manifest in the buttocks and lower extremity
    - Can involve sensory and motor deficits and/or changes in reflexes
    - Lumbar radiculopathy: impingement of lumbar roots and/or spinal nerves that results in pain/numbness radiating down the lower extremity (e.g. sciatica)
  - Lumbar spinal nerve reflexes
    - L4 – patellar tendon
    - S1 – Achilles tendon

C. Sympathetic Chain
- Pair of trunk structures that travel along the lateral surface of the vertebral bodies
- Begins in the thorax region at T1 vertebra and descends the vertebral column
- Both trunks course medially in the sacral region and converge on the ganglion impar → anterior to the coccyx
- Passageway and synapse point for sympathetic fibers
- Left sympathetic trunk travels just lateral to the thoracic and abdominal aorta

V. Blood Vessels
A. Aorta
- Descends along anterior surface of the vertebral bodies in the thorax and abdomen
  - At risk during discectomy spine surgery procedures
- Bifurcates into the common iliac arteries at L4 vertebral level in the abdomen
B. Vertebral Artery
- Arises from the subclavian artery, then enters the transverse processes of the cervical vertebrae at the C6 vertebral level
- Ascends through the transverse foramen of each cervical vertebra and exits at the C1 vertebral level
- Travels across the posterior arch of C1 and through the suboccipital triangle before entering the skull through the foramen magnum
- Within the skull, the two vertebral arteries join to form the basilar artery, which is the main supply to the brainstem
- Excessive manipulation or trauma to the cervical vertebrae can create an embolism in the vertebral arteries that can travel to the cerebral circulation and result in a stroke
C. Vertebral Venous Plexuses
- Internal vertebral venous plexus is located in the epidural space forming anterior and posterior venous networks that travel the length of the vertebral column
  - Communicates superiorly with the cranial dural sinuses
  - Inferiorly communicates with the prostatic venous plexus, which is believed to be a conduit for prostate carcinoma to metastasize to the spine
- External vertebral venous plexus forms an anterior part that travels anterior to the vertebral column and a posterior part that travels on the vertebral arch externally
  - Forms anastomosis with the internal vertebral venous plexus

VI. Clinical Pearls
A. Lumbosacral Strain
- Strain of the lower back muscles
- Causes: physical exertion, poor form when lifting, overuse or trauma
- Presentation: low back pain that does not radiate, usually following a clear causative incident
- Physical exam: tenderness to palpation over the paraspinal muscles, (-) Straight Leg Test and normal neurological exam
- Treatment: NSAIDs and early mobilization, exercises or physical therapy

B. Disc Herniation
- Cervical
  - Presentation: neck, shoulder and/or arm pain, weakness and numbness
  - Rule out: torticollis, shoulder pathology, carpal tunnel, neurological disease and peripheral vascular disease (brachial and radial pulses)

Table 2.6: Physical Exam Findings for Cervical Disc Herniations

<table>
<thead>
<tr>
<th>Physical Exam</th>
<th>C5</th>
<th>C6</th>
<th>C7</th>
<th>C8</th>
<th>T1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensory</td>
<td>Lateral shoulder</td>
<td>Thumb</td>
<td>Middle finger</td>
<td>Ring and small fingers</td>
<td>Medial forearm and hand</td>
</tr>
<tr>
<td>Motor</td>
<td>Weak shoulder abduction</td>
<td>Weak elbow flexion</td>
<td>Weak elbow extension</td>
<td>Weak finger abduction</td>
<td>Weak finger abduction</td>
</tr>
<tr>
<td>Reflex</td>
<td>Hypoactive biceps brachii</td>
<td>Hypoactive brachioradialis</td>
<td>Hypoactive triceps</td>
<td>No abnormal reflex</td>
<td>No abnormal reflex</td>
</tr>
</tbody>
</table>
Lumbar
- Presentation: low back, buttocks and/or leg pain, weakness and numbness
- Special tests: (+) Straight Leg Test, abnormal gait (walking on heels/toes)
- Rule out: abdominal/pelvis pathology, hip pathology, knee pathology, neurological disease and peripheral vascular disease (posterior tibial and dorsalis pedis pulses)

Table 2.7: Physical Exam Findings for Lumbar Disc Herniations

<table>
<thead>
<tr>
<th>Physical Exam</th>
<th>L3</th>
<th>L4</th>
<th>L5</th>
<th>S1</th>
<th>S2-S4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensory</td>
<td>Anterior and medial thigh</td>
<td>Medial leg and ankle</td>
<td>Dorsal foot and 1st webspace</td>
<td>Lateral and plantar foot</td>
<td>Perianal sensation</td>
</tr>
<tr>
<td>Motor</td>
<td>Knee extension</td>
<td>Ankle dorsiflexion</td>
<td>Big toe dorsiflexion</td>
<td>Ankle plantar flexion</td>
<td>Anal squeeze</td>
</tr>
<tr>
<td>Reflex</td>
<td>No abnormal reflex</td>
<td>Hypoactive patellar tendon</td>
<td>No abnormal reflex</td>
<td>Hypoactive Achilles tendon</td>
<td>Hypoactive bulbocavernosus</td>
</tr>
<tr>
<td>Gait</td>
<td>N/A</td>
<td>N/A</td>
<td>Walking on heels, foot drop</td>
<td>Walking on toes</td>
<td>N/A</td>
</tr>
</tbody>
</table>

- Diagnosis: MRI confirms diagnosis and can show impingement of spinal nerves
- Treatment: physical therapy, corticosteroid injections and/or surgery

C. Spinal Stenosis
- Narrowing of the spinal canal and/or the transforminal foramina
- Usually due to degenerative joint disease resulting in bone spurs, ligament hypertrophy, facet joint breakdown and cyst formation
- Other causes: degenerative disc disease, retropulsion of bone fragments during vertebral fractures, spondylolisthesis, spine trauma and tumors
- Presentation: low back pain that radiates bilaterally into the buttocks and lower extremities; numbness; weakness; bladder/bowel incontinence
  - Pain is worse with standing and extension
  - Pain is better with flexion and leaning forward (Shopping Cart Sign)
- Neurogenic claudication: patient is unable to walk distances due to significant leg pain, similar to patients with peripheral vascular disease of the lower extremities
Spine & Upper Extremity

- Physical exam: bilateral numbness, weakness, hypoactive reflexes, abnormal gait and/or absent anal reflex
- Diagnosis: X-ray, CT and MRI
- Treatment: physical therapy, corticosteroid injections and/or surgery

D. Spondylolysis
- Fracture or defect of the pars interarticularis without slippage of the vertebral bodies
- Common in injuries that involve hyperextension of the spine (gymnasts, linemen in football) and often seen in children
- Most common site is L5 vertebra
- Presentation: low back pain that is worse with activity
- Diagnosis: X-ray, CT and MRI
- Treatment: rest, physical therapy – lumbar flexion exercises, lumbar brace, surgery is uncommon unless the patient also develops vertebral instability (e.g. spondylolisthesis)

E. Spondylolisthesis
- Slippage of one vertebra on another (usually refers to anterior translation)
- Causes: degenerative arthritis, traumatic, isthmic and dysplastic
- Bilateral spondylolysis can lead to a spondylolisthesis
- Presentation: low back pain worse with activity, pain that radiates down the lower extremity, numbness, weakness and difficulty ambulating
- Physical exam: decreased range of motion, semi-kypotic posture, abnormal gait and/or motor and sensory deficits
- Diagnosis: X-ray, CT and MRI for visualizing damage to neurologic structures
- Treatment: rest, physical therapy, bracing and/or surgery

F. Abnormal Curvatures
- Excessive Kyphosis (hyperkyphosis)
  - Excessive thoracic (primary) curvature
  - Causes: osteoporosis eroding anterior thoracic vertebrae, disuse or atrophy of deep back muscles and whiplash injury (cervical spine)
  - Presentation: difficulty getting up from a chair, feeling off-balance, difficulty ambulating, fatigue and respiratory problems in severe disease
  - Diagnosis: X-ray
  - Treatment: treat underlying cause and physical therapy

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**Figure 2.34**: Oblique X-ray of a Lumbar Spondylolysis

**Figure 2.35**: Lateral X-ray of Lumbar Spondylolisthesis

**Figure 2.36**: AP X-ray of Sacroiliitis in Ankylosing Spondylitis

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Spine & Upper Extremity

- Excessive Lordosis (hyperlordosis)
  - Excessive lumbar (secondary) curvature
  - Causes: muscle strength and length imbalances, weak anterior abdominal wall muscles, osteoporosis, achondroplasia, spondylolisthesis and osteoporosis
  - Pregnant women temporarily acquire during late gestation – adjust center of gravity due to fetal growth
  - Diagnosis: X-ray
  - Treatment: muscle stretching, bracing and treating an underlying cause if present

- Scoliosis
  - Abnormal lateral curvature and long axis rotation of the spine
  - Types: congenital, idiopathic and neuromuscular
  - Presentation: asymptomatic; pain in the back, shoulders and neck; respiratory problems in severe disease
  - Physical exam: spinal deformity on Forward Bending Test, asymmetric weakness of intrinsic back muscles and asymmetric lower extremity lengths
  - Neurological deficits usually only seen in neuromuscular type
  - Diagnosis: full length spinal X-rays (AP and lateral views)
  - Treatment: observation, bracing, activity restriction and/or surgery

G. Ankylosing Spondylitis
- Systemic autoimmune disease that primarily affects the spine, especially where it articulates with the pelvis
- Leads to fusion of the spine in an ascending manner from lumbar to the cervical region
- Presentation: low back pain and stiffness, neck pain later in the disease, inflammation at tendinous insertions into bone (Achilles and supraspinatus tendons), chest pain and respiratory problems with thoracic spine involvement
- Labs: ESR and HLA-B27
- Complications: eventually the spine can become brittle and prone to fractures with minimal trauma
  - With advanced disease, the lumbar spine can lose lordosis resulting in an inability to stand upright
- Diagnosis: X-ray showing sacroiliitis – sclerotic changes in the sacroiliac joints
- Treatment: NSAIDs, immunotherapies, physical therapy and surgery for severe cases

H. Conus Medullaris Syndrome
- Injury or compression of the conus medullaris
- Causes: trauma, tumor, spinal stenosis and pathology in the epidural space compressing the conus medullaris (e.g. abscess, hematoma)
- Presentation: acute onset severe low back pain; bilateral motor and sensory deficits in the lower extremities; perianal numbness; early onset bowel and bladder dysfunction
- Physical exam: hyperreflexia and absent anal reflex
- Diagnosis: MRI
- Treatment: emergent surgical decompression

I. Cauda Equina Syndrome
- Injury or compression of the cauda equina
- Causes: trauma, space-occupying lesions within the lumbosacral canal – disc herniation (most common), spinal stenosis, tumor, epidural hematoma and epidural abscess
- Presentation: acute onset severe low back pain; severe radicular pain that is often unilateral, perianal numbness, asymmetric motor and sensory deficits in the lower extremities; later onset bowel and bladder dysfunction
- Physical exam: diminished or absent reflexes and absent anal reflex
- Diagnosis: MRI
- Treatment: emergent surgical decompression
J. **Epidural Abscess**
- Collection of pus that has formed in the epidural space of the spinal canal
- Most common organism: *Staphylococcus aureus*
- Risk factors: IV drug abuse, diabetes and immunodeficiency
- Presentation: low back pain, fever and neurological deterioration
- Labs: CBC, ESR and CRP
- Diagnosis: MRI
- Treatment: antibiotics, emergent surgical decompression and evacuation

K. **Spinal Tumors**
- Common site for metastasis: lymphoma, melanoma, breast, lung, prostate, colorectal and renal carcinoma
  - Presentation: back pain, muscle weakness/paralysis, abnormal reflexes and/or acute neurological deterioration
  - Diagnosis: X-ray, CT and MRI
  - Treatment: surgical resection, radiation therapy and chemotherapy
- Multiple myeloma is a cancer of plasma cells that results in abnormally large production of antibodies that affects several organ systems, often including the spine
  - Presentation: back pain, bone pain, renal failure, infection, hypercalcemia and anemia
  - Can have spinal cord compression leading to neurological deficits
  - Spine complications: lytic lesions, pathological fractures, structural deformity and anemia from infiltration of the vertebral bone marrow
- Tumors of the spinal cord and meninges are very rare, but can cause significant neurological deficits and disability
  - Examples: schwannomas, neurofibromas, meningiomas, astrocytomas and ependymomas